Form 1220–5
(January 1974)

Filing Code

Date Issued

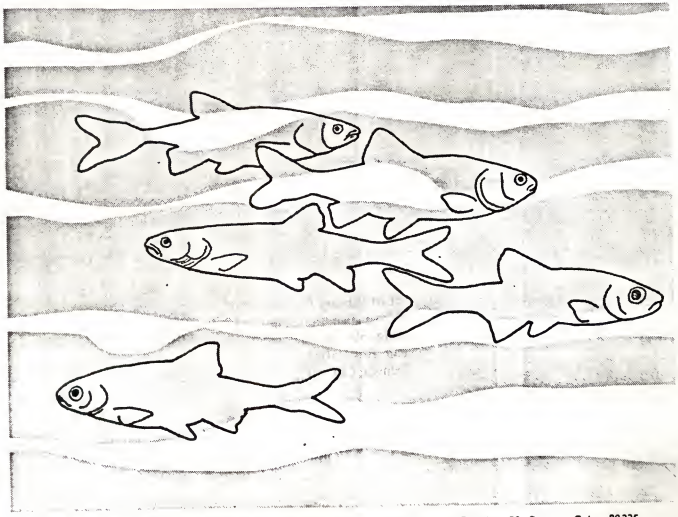
TECHNICAL NOTE

U.S. DEPARTMENT OF THE INTERIOR – BUREAU OF LAND MANAGEMENT

FISHERIES and AQUATIC HABITAT INVENTORY and ANALYSIS TECHNIQUES

by

P. Cuplin, C. Armour, R. Corning
D. Duff and A. Oakley



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#41735111 ID: 88073785 QL 84.2 .L35

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ABSTRACT

This technical note presents fisheries and aquatic inventory and analysis strategies not available in other Bureau of Land Management documents.

Minimal standards for fisheries and aquatic data collection and analysis are discussed for planning and environmental statements.

Stream survey, lake, pond and reservoir survey, macroinvertebrate collection and analysis, water chemical analysis, fish sampling and methods of estimating inventory costs are discussed.

INTRODUCTION

The objectives of this technical note are threefold: first to provide sampling strategies for stream, macroinvertebrate and fish surveys; second to identify minimal data needed for stream and lake surveys, and water chemical analysis; and third to present methods for analysis and description of existing aquatic habitat conditions for planning and environmental statements.

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STREAM SURVEY

Sampling Intensity. Data for data elements listed below should be compiled for each perennial and important intermittent stream, with data collections to be carried out at one mile intervals (by definition, an important intermittent stream is one that is necessary for completing life cycle phases of one or more aquatic community members which normally inhabit adjoining perennial streams, i.e., such as a stream used in the Spring for spawning purposes by certain fishes). Site Specific Data is to be collected within 1/10 mile i.e., 528 foot long, segments which are to be established at one mile intervals.

Data Elements

Stream name (use Form 6671-1)
Stream order
Stream classification (State or other)
Total miles of fish habitat
Location of inventory section (map coordinates and narrative)
Elevation (feet above mean sea level)
Land ownership
Average gradient
Stream stage
Stream discharge.
Average stream width (wetted perimeter at time of survey and estimated at time of spawning for major fish species)
Average channel width (bank to bank)
Average depth
Pool/riffle ratio
Streamside vegetation (major types growing in close proximity to the stream)
Adjacent landform (including vegetative type, percent slope, and geologic landform type)
Riparian zone width (on each bank)
Composition of stream bottom materials (total 100%)
Barriers to upstream fish migration
Condition of spawning habitat for game, commercial, and endangered, threatened, or sensitive species.
Water temperature (time, weather and air temperature)
Turbidity (visibility)
USFS stream-reach inventory and channel stability evaluation
Water analysis for:
- pH
- Specific conductance in micromohs
- Total alkalinity

Factors limiting stream productivity, by apparent ranking in importance
Access

Stream Habitat Inventory Profile (SHIP), based on ratings of the following data elements. See Illustrations 1 and 2.

High stream shade
Condition of low stream bank vegetation and bare soil percent
Stream bank stability
Stream channel stability
Sedimentation accumulation of streambed

Stream Habitat Analysis. Illustrations 1 and 2, the field inventory and photo interpretation forms, offer a self explanatory analysis system that is based upon a numerical rating system for each of the five catagories shade, percent bare soil of low stream bank, stream bank stability, stream channel stability, and sediment percentage on the stream bottom.

FISH SPECIES SAMPLING

Sampling Intensity. At least one fish species sampling should be made in each perennial stream within the area to be inventoried. One or more fish species sampling should also be obtained from each intermittent stream that is deemed important because of use by fishes (if fish are present at the time sampling is to be conducted).

Fish Species Data Collection. Qualitative fish species sampling may be obtained with electrofishing gear, seines, net, approved toxicants, hook and line, or other appropriate methods. The following information should be collected: 1) Species composition of the stream and relative abundance of major fish species, 2) Catch per unit effort or catch per linear distance for each species captured, and 3) Total length information for each species recovered.

Fish Population Sampling. In the event that special studies or monitoring change in streams require fish population sampling the outlined procedures should be followed.

Sampling Procedure. Block both ends of each previously determined 1/10 mile (528 feet) sampling station with block nets. Collect samples with electrofishing gear, using the Seber-LeCren double sampling procedure (See Appendix). Make Seber-LeCren population estimates for important game, sensitive, endangered or threateded fishes. Streams too large (deep) to wade safely are not to be sampled unless they are sampled in conjunction with personnel of the appropriate state fish and game agency, and gear satisfactory for use on large streams and rivers is available. The following information is required for each sampling station.

Fish Population Estimates for important fishes, by species (if sample size is too small to allow the computation of a 95% confidence interval within $\pm$ 30% of N, do not make the computation). Express population estimates in numbers per linear mile and in numbers per surface acre.

Relative Abundance Estimates for all fish species as numbers per unit of effort or per linear mile.

Fish Length Distributions (using total length), by species.

Total Pounds of Fish present, in pounds per acre and per mile, for each species (if population estimates can be made as described in fish population estimates above, use estimates to expand poundage data to total pounds estimated to be present).

MACROINVERTEBRATE SAMPLING

Sampling Intensity. Benthic samples should be collected from all perennial streams at the same time and locations as are established for the fish species sampling. Four (4) square-foot stream bottom samples will be collected and kept separately for later data analysis. Sampling analysis should be contacted with a qualified taxonomist. Data recorded at sampling site should include: stream, sample number, sample site, substrate composition and average size range, estimated stream velocity in fps, cfs flow, water depth at sampling site, and any unusual circumstances such as flood stage conditions.

Collection Data. (Use Form 6675-1) Sampling should be carried out in areas of maximum benthos productivity using the following guidelines:

Stream flow--velocity .2 to .6 meters (.75 to 2.0 fps). Do not sample in areas with stream flows less than .4 fps.

Substrate--Stream bottom material 7.6 to 12.0 cm (3 to 5 inches) in diameter in riffle-rubble area. If a stream does not have sampling sites of this type, sample in next productive type.

Data Separation. Contract analysis should provide the following data:

1. An abundance rating for the collection site in number of organisms per square meter: Poor 0 to 1074 organisms/M^2, Average 1074-2148 organisms/M^2, or Rich greater than 2148 organisms/M^2.

2. The appropriate Shannon-Wiener (formerly Shannon-Weaver) diversity indices (See Appendix 3).

3. A list of organisms (by individual taxa) to at least the genus taxonomic level.

LAKE, POND AND RESERVOIR INVENTORIES.

Sampling Intensity. A complete inventory as described in BLM Manual 6672 may be required for waters supporting the most important fisheries, or where special use problems are known to exist. This need is to be determined by appropriate State and District personnel. In all other cases, the data listed below should be compiled for all lakes, ponds, and reservoirs.

Sampling Needs. The following information is to be collected during field inventories:

Water type (Use 6677-3 and Water Class Matrix Appendix 5)
Water class
Surface acres
Miles of shoreline
Shore development
Elevation of water surface, normal or maximum (specify)
Maximum width
Maximum depth
Shoal area (percent)
Shoreline ownership
Inlet tributaries and outlet stream(s) (name)
Fish species present
Fish stocking activities
Fish reproduction
Access to water
Shoreline composition (visual, percent rock, soil and vegetation)
Shoreline vegetative composition (visual - none or very sparce cover, grasses/sedges dominant, shrub dominant, or trees dominant)
Habitat condition (good, fair, or poor)
Habitat trend (improving, static, or deteriorating)
Type of fishery (cold water, intermediate, or warm water)
Limiting factors to productivity
Secchi disc reading
Air temperature
Water temperature
Water analysis for:

- Dissolved oxygen in mg/l
- Carbon dioxide in mg/l
- Alkalinity (total) in mg/l
- pH
- Specific conductivity

If Apparently Suitable Waters are unproductive of fish, the following water analyses should be taken during the midsummer and midwinter.

Secchi disc readings (Use 6674-3)
Water temperature at periodic depths
Dissolved oxygen
Total alkalinity
pH
Specific conductivity

ESTIMATING INVENTORY COSTS AND MANPOWER NEEDS

Streams

Information Needed. The following information is needed to estimate inventory costs and manpower needs assuming the use of a two person field crew. The number of perennial and important intermittent streams in the inventory area.

Estimating Procedures. Multiply the estimated number of perennial and important intermittent streams within the sampling area by 4 hours to arrive at the estimated total number of hours required to carry out fish species sampling and to collect macroinvertebrate samples (it is assumed sampling requires approximately 2 hours of field time, including travel, and is carried out by a 2 person crew).

Total Hours Required for Stream Surveys. Multiply the estimated total miles of perennial and important intermittent streams by 4 hours (estimated time for a 2 person crew to complete field work) to arrive at the estimated total person hours required to carry out stream data inventories.

Summary of Hours Required for Field Inventories. Summarize estimated person hours for A., B., and C. above. This represents the total number of person hours effort required for conducing stream field inventories of the sampling area.

Estimated Hours Required for Office Procedures. Divide the summary hours by 4 (assumes office time will approximate 1/4 the amount of time necessary for conducting field work). The product represents the total estimated person hours required for carrying out office preparations and for compiling data from non-field sources.

Estimated Number of Hours Required for Field Inventory. Add summary and estimated hours together. The product is the estimated total number of person hours required for carrying out the comprehensive stream field inventory.

Estimated Cost of Macroinvertebrate Sample Analysis. Multiply the total number of estimated perennial and important streams in the inventory area by $30 (estimated processing and analysis cost per macroinvertebrate sample), or by an estimate of individual sample cost as provided by potential contractors. This is the total estimated cost of sorting and analyzing macroinvertebrate samples from streams.

Calculation of Cost for Minimal Stream Inventory. Multiply the estimated number of hours required for field inventory by $11 (estimated hourly salary rate). Add estimated cost of macroinvertebrate sample analysis and calculation of cost for minimal stream inventory together. This represents the total estimated expenditure necessary for carrying out minimal stream field inventories.

Use of Estimating Procedures.

Assumed Situation. The estimated number of perennial and important intermittent streams in the Lost River Environmental Statement (LRES) area is 120. A total of 20 streams prepresenting 60 stream miles have been determined to be small first order streams with similar characteristics i.e., a lesser number of samples required for fish population and macroinvertebrate sampling according to procedures outlined for determining sampling intensities (See .31). Because similar small headwater streams comprise 60 of the total stream miles, this number of stream miles is subtracted from the 1760 estimated to exist in the LRES area for fish species sampling. Two additional samples are added to the overall estimate (two samples to be collected within the 60 stream miles of the comparable first order streams).

Computations.

1. 120 x 4 = 480 person hours to carry out fish species sampling and macroinvertebrate collecting.

2. 1,760 x 4 hours = 7,040 hours for conducting stream inventories.

3. 480 person hours
+2,736
+7,040
10,256 person hours

4. 10,256/4 = 2,564 person hours for office preparations and data compilation for streams.

5. 10,256
+2,560
12,816 person hours for carrying out the comprehensive stream field inventory.

6. 120 streams x $30 per sample = $3,600 for sorting and analyzing macroinvertebrate samples.

7. 12,816 person hours x $11 per hour = $140,976.

8. $140,976
+ 3,600
$144,576 to cary out a minimal stream field inventory of the LRES area (120 streams having a combined length of 1,760 miles).

STREAM HABITAT INVENTORY PROFILE

(This form to be used for field inventory or photo interpretation)

Stream _____ Date _____ Surveyor(s) _____ State _____ Dist. _____

Planning Unit _____ Site No. _____ Length of Stream Surveyed _____

Field Survey _____ Aerial Photograph _____ (Check one)

Stream Cover (% Shade)	80%+	4	60 - 80%	3	40 - 60%	2	40% or less	1
Stream Bank Condition (% Bare Soil)	5% or less	4	6 - 15%	3	16 - 25%	2	25% or more	1
Stream Bank Stability (% Bank Damage)	0 - 10%	4	20% or less	3	40% or less	2	41% or more	1
Stream Channel Stability (% Channel Movement)	5% or less	4	6 - 10%	3	11 - 15%	2	16% or more	1
Sedimentation of Streambed (% Silt)			10% or less	3	11 - 25%	2	26% or more	1
Column Totals	[_____]		[_____]		[_____]		[_____]	

Stream Condition Rating for Length of Stream Evaluated - (Enter total score in appropriate space)

Excellent 17 _____ Good 14-16 _____
Fair 10-13 _____ Poor 5- 9 _____

SUMMARY (Last page of inventory for each stream)

Field Inventory Total Number Stream Sites _____
Stream Condition Rating No. Miles: Excellent _____ Good _____ Fair _____ Poor _____

Photo Interpretation Total Number Stream Miles Inventoried _____
Stream Condition Rating No. Miles: Excellent _____ Good _____ Fair _____ Poor _____

A. High Stream Cover (June - September; 11:00 am - 5:00 pm, MDT) — Rating

80% + — 4. ___ Excellent

60 - 80% — 3. ___ Good

40 - 60% — 2. ___ Fair

Less than 40% — 1. ___ Poor

B. Stream Bank Condition upper watershed — Rating

No negligible use/damage; vegetation 1/ well-rooted; sod intact; very little, if any erosion from vegetation areas, less than 5% bare soil showing. — 4. ___ Excellent

Some use/damage; vegetation generally well-rooted; sod mostly intact; soil showing in places (6% to 15% bare soil showing overall); some surface erosion evident. — 3. ___ Good

Use or damage close to sod; vegetation shallow-rooted; moderated surface erosion (16% to 25% bare soil showing overall). — 2. ___ Fair

Heavy to severe use/damage; vegetation generally cropped to sod; considerable soil showing (over 25%) with sod damage serious; active surface erosion a serious problem. — 1. ___ Poor

1/ Primarily grasses, sedges and forbs.

C. Stream Bank Stability - near stream — Rating

Bank Stable and Undamaged - Partial or no evidence of bank damage; 90-100 percent of bank area free from use/damage. Little or no unnatural bank erosion or sloughing present. — 4. ___ Excellent

Bank Damage 20 Percent or Less - Banks 80 to 90 percent free from use/damage. Some erosion and sloughing but fully recoverable after a season of rest. — 3. ___ Good

Bank Damage 40 Percent or Less - Banks having received 20 to 40 percent damage from use/damage. Moderate to heavy bank erosion and sloughing during season(s) of use, and which continues during no use period(s). Conditions will not allow natural stability recovery of banks to a level greater than 60 percent stability. — 2. ___ Fair

Bank Damage Excessive - Banks exhibiting greater than 40 percent damage. Severe bank damage and accelerated erosion and sloughing is present over virtually the entire bank surveyed. No evidence of bank recovery visible, and erosion is consistent. — 1. ___ Poor

D. Stream Channel Stability - movement — Rating

No negligible lateral channel movement and bank erosion (cutting) (5%), scour, or changing channels. — 4. ___ Excellent

Some lateral channel movement and bank erosion (5 to 10%), minor channel scour or changing channels within stream bed. — 3. ___ Good

Frequent lateral channel movement (10 to 15%); moderate channel scour or channel change within stream bed. — 2. ___ Fair

More than 20% lateral channel movement and bank cutting, changing channels and severe scour evident, and source of extreme sedimentation. — 1. ___ Poor

E. Sedimentation of Stream Bed - Percent of fine sediments (particles sand size and smaller) covering stream bottom (wetted parameter) materials. — Rating

Less than 10% — 3. ___

10 - 25% — 2. ___

More than 25% — 1. ___

ILLUSTRATION 2

LOCATION

State _____ District _____ Planning Unit _____ Survey Date _____

Surveyor(s) _____ Stream Name _____

Survey Location _____

INVENTORY MEASUREMENTS & ESTIMATES*

Stream Size & Discharge { Survey Date _____ Width _____ ft. Ave. Depth _____ ft. Velocity _____ f/s Discharge _____ cfs
At Maximum _____ ft.* _____ ft.* _____ f/s* _____ cfs*

Gradient _____ % Sinuosity ratio _____ Stream Order _____ Turbidity Level _____ Stream Stage _____

Channel Flow Pattern _____

f/s = 100' / 20 sec.

Soils Description _____

Landform and/or Geologic Type _____

f/s x width x depth x .8 rough
.9 smooth = cfs

Vegetative Type _____

Number of debris jams &/or fish blocks/mile _____. Upstream watershed impacts (Types) _____

Size Composition of Bottom Materials (Total to 100%)

1. Exposed bedrock..... ___%
2. Large Boulders, 3' + Dia.... ___%
3. Small boulders, 1-3'..... ___%
4. Large rubble, 6"-12"..... ___%
5. Small rubble, 3"-6"..... ___%
6. Coarse gravel, 1"-3"..... ___%
7. Fine gravel, 0.1"-1"..... ___%
8. Sand, silt, clay, muck... ___%

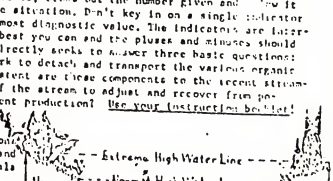
Weather and Other Remarks _____

Pool/riffle Ratio _____ Riparian Zone Width _____ (Both Sides)

INSTRUCTIONS

Use a separate rating form for each length of stream that appears similar. Complete the inventory items above using maps, aerial photos, and field observations and measurements. On the opposite side of this page, the channel and adjacent flood plain banks are subjectively rated, item by item, following an on-the-ground inspection. Circle only one of the numbers in parentheses for each item rated. If actual conditions fall somewhere between the conditions as described, cross out the number given and show it write in an intermediate value which better expresses the situation. Don't key in on a single indicator or a small group of indicators but use them all for the most diagnostic value. The indicators are interrelated so don't dwell on any one item for long. Do the best you can and the pluses and minuses should balance out. Keep in mind that each item directly or indirectly seeks to answer three basic questions: (1) What are the magnitude of the hydraulic forces at work to detach and transport the various organic and inorganic bank and channel components? (2) How resistent are these components to the recent streamflow forces exerted on them? (3) What is the capacity of the stream to adjust and recover from potential changes in flow volume and/or increases in sediment production? Use your instruction booklet!

DEFINITION OF TERMS AND ILLUSTRATIONS



Upper Bank - That portion of the topographic cross section from the break in the general slope of the surrounding land to the normal high water line. Terrestrial plants & animals normally inhabit this area.

Lower Banks - The intermittently submerged portion of the channel cross section from the normal high water line to the water's edge during the summer low flow period.

Channel Bottom - The submerged portion of the channel cross section which is totally an aquatic environment.

Bottom Slope - The height of water in the channel at the time of rating is recorded on the top half of this page using numbers 1 through 5. These numbers, as shown below, relate to the surface water elevation relative to the normal high water line. A decimal division should be used to more precisely define conditions, ie. 3.5 means 1/2the of the channel banks are under water at the time of rating.

5 = Flooding. The flood plain is completely covered.
4 = High. Channel full to the normal high water line.
3 = Moderate. Bottom and 1/2 of lower banks wetted.
2 = Low. Bottom covered but very little of the lower banks wet.
1 = "Dry". Essentially no flow. Water may stand in bottom depressions.

* Use an asterisk behind all estimates that could be measured but weren't.

ILLUSTRATION 2 (Cont.)

Item Rated	Stability Indicators by Classes								
	EXCELLENT		GOOD		FAIR		POOR		
UPPER BANKS									
Landform Slope	Bank slope gradient <30%	2	Bank slope gradient 30-40%	4	Bank slope gradient 40-60%	6	Bank slope gradient 60%+	8	
Mass Wasting Existing or Potential	No evidence of past or potential for future mass wasting into channels.	3	Infrequent and/or very small. Mostly healed over. Low future potential.	6	Moderate frequency & size, with some raw spots eroded by water during high flows.	9	Frequent or large, causing sediment nearly yearlong or imminent danger of same.	12	
Debris Jam Potential Floatable Objects	Essentially absent from immediate channel area.	2	Present but mostly small twigs and limbs.	4	Present, volume and size are both increasing.	6	Moderate to heavy amounts, predominantly larger sizes.	8	
Bank Protection from Vegetation	90% + plant density. Vigor and variety suggests a deep, dense root mass.	3	70-90% density. Fewer plant species or lower vigor suggests a less dense or deep root mass.	6	50-70% density. Lower vigor and still fewer species form a somewhat shallow and discontinuous root mass.	9	<50% density plus fewer species & less vigor indicate poor, discontinuous, and shallow root mass.	12	
LOWER BANKS									
Channel Capacity	Ample for present plus some increases. Peak flows contained. W/D ratio<7.	1	Adequate. Overbank flows rare. Width to Depth (W/D) ratio 8-15.	2	Barely contains present peaks. Occasional overbank floods. W/D ratio 15-25.	3	Inadequate. Overbank flows common. W/D ratio 25.	4	
Bank Rock Content	65%+ with large, angular boulders 12"+ numerous	2	40-65%, mostly small boulders to cobble 6-12".	4	20-40%, with most in the 3-6"diameter class.	6	<20% rock fragments of gravel sizes, 1-3" or less.	8	
Obstructions Flow Deflectors Sediment Traps	Rocks, old logs firmly embedded. Flow pattern of pool & riffles stable without cutting or deposition.	2	Some present, causing erosive cross currents and minor pool filling. Obtions and deflectors newer and less firm.	4	Moderately frequent, moderately unstable obstructions & deflectors move with high water causing bank cutting and filling of pools.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sed. traps full, channel migration occuring.	8	
Cutting	Little or none evident. Infrequent raw banks less than 6" high generally.	4	Some, intermittently at outcurves & constrictions. Raw banks may be up to 12"	8	Significant. Cuts 12-24" high. Root mat overhangs and sloughing evident.	12	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16	
Deposition	Little or no enlargement of channel or point bars.	4	Some new increases in bar formation, mostly from coarse gravels.	8	Moderate deposition of new gravel & coarse sand on old and some new bars.	12	Extensive deposits of predominately fine particles. Accelerated bar development.	16	
BOTTOM									
Rock Angularity	Sharp edges and corners, plane surfaces roughened.	1	Rounded corners & edges, surfaces smooth & flat	2	Corners & edges well rounded in two dimensions.	3	Well rounded in all dimensions, surfaces smooth.	4	
Brightness	Surfaces dull, darkened, or stained. Gen. not "bright".	1	Mostly dull but may have up to 35% bright surfaces.	2	Mixture, 50-50% dull and bright, + 15%, i.e., 35-65%	3	Predominately bright, 65%+ exposed or scouted surfaces.	4	
Consolidation or Particle Packing	Assorted sizes tightly packed and/or overlapping.	2	Moderately packed with some overlapping.	4	Mostly a loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8	
Bottom Size Distribution	No change in sizes evident.	4	Distribution shift slight. Stable materials 50-80%.	8	Moderate change in sizes. Stable materials 20-50%.	12	Marked distribution change. Stable materials 0-20%.	16	
Percent Stable Material	Stable materials 80-100%								
Scouring and Deposition	Less than 5% of the bottom affected by scouring and deposition.	6	5-30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30-50% affected. Deposits & scour at obstructions, constrictions, and bends. Some filling of pools.	18	More than 50% of the bottom in a state of flux or change nearly yearlong.	24	
Clinging Aquatic Vegetation Moss & Algae	Abundant. Growth largely moss like, dark green, perennial. In swift water too.	1	Common. Algal forms in low velocity & pool areas. Moss here too and swifter waters.	2	Present but spotty, mostly in backwater areas. Seasonal blooms make rocks slick.	3	Perennial types scarce or absent. Yellow-green, short term bloom may be present.	4	
COLUMN TOTALS									

Record the values in each column for a total reach score. (E.___+ G.___+ F.___+ P.___ = __)

Reach score of: 38 = Excellent, 39-76 = Good, 77-114 = Fair, 115+ = Poor.

ILLUSTRATION 5

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

STREAM SURVEY REPORT

Date
Surveyor
Agency

Stream	Tributary		Basin
Location (Stream mouth)	Township	Range	Section
County	State Administration Unit Number		Code Number
Stream Order	Stream Classification		Miles of Fish Habitat

PHYSICAL SURVEY DATA

Location of Inventory Section	Length of Stream Surveyed
Elevation (ft above sea level)	Land Ownership
Stream width (average) ft. today ft. when _____ spawn ft. when _____ spawn	Channel width (average _____ Streamside Vegetation _____ Riparian width (both sides of stream) Land form adjacent to stream
Stream depth (average)	

WATER ANALYSIS

pH	Specific Conductivity μ mohs/cc	Alkalinity (total)	Spawning Habitat for Fish (Describe Conditions)

TURBIDITY (Visibility in Feet)

MUDDY		MURKY		CLEAR	
<.5	.5-1	1-2	2-5	5-10	10 +

Temperature: Air °F, Water °F, Time , Flow (c.f.s.) Now , High , Low

GRAVEL, POOL AND RUBBLE AREA

SUBSECTION	FISH SPECIES	GRAVEL (sq. yards) GOOD	MARGINAL	TOTAL	POOLS SQ. YARDS	DEPTH	RUBBLE (sq. yards)	TOTAL (sq. yards)
Total								

PERCENT OF SECTION IN POOLS

0	10	20	30	40	50	60	70	80	90	100

Gradient
- [ ] Steep (2.5 + %)
- [ ] Moderate (1.0 to 2.5%)
- [ ] Flat (0 to 1%)

AVERAGE STREAM AREA SHADED (percent)

0	10	20	30	40	50	60	70	80	90	100

STREAMSIDE COVER TYPE

LOGGED WITHIN (years) 0-5	6-10	GROWTH 2nd	OLD	HERB	OTHER

FISH SPECIES, SIZE, AND ABUNDANCE

Method of collection

SPECIES	SIZE	NUMBER PER 100 FT. 0-5	6-50	50 +	SPECIES	SIZE	NUMBER PER 100 FT. 0-5	6-50	50 +

LIMITING FACTORS

BARRIERS (type) DAM	FALLS	LOGJAM	CULVERT	HEIGHT (ft.)	PASSABLE YES	NO	CORRECTIONS NEEDED YES	NO

Other factors limiting stream productivity

Access

Form 6677-1

ILLUSTRATION 3 (Cont.)
(Back of Form 6677-1)

FISH SAMPLING

Fish Species Composition	Catch/Unit of Effort	Total Length of Fish by Species

FISH POPULATION ESTIMATE
NO. FEET OF STREAM ELECTROFISHED

FIRST SAMPLE		SECOND SAMPLE	
Species	No.	Species	No.

Game Fish/Mile_____ Nongame Fish/Mile_____

Additional Comments

INSTRUCTIONS
(Items not mentioned are self-explanatory)

Form 6677-1

STREAM

Tributary to -- Enter name of creek, river or body of water into which surveyed stream flows.

Basin -- Enter name of major drainage basin.

COUNTY -- Give county(ies) where stream is located.

STATE ADMINISTRATIVE UNIT NUMBER (S.A.U. #) -- Give appropriate administrative district number.

STREAM ORDER -- First order streams are unbranched reaches found usually but not exclusively at the head of drainage basins. Second order streams are formed when two or more first order reaches come together.

STREAM CLASSIFICATION -- Based on rating determined from Stream Habitat Inventory Profile (SHIP) in evaluation of High Stream Shade, condition of low stream bank vegetation and bare soil percentage, stream bank stability, stream channel stability and stream bed sediment.

MILES OF FISH HABITAT -- The number of miles of stream that will support fish of any species.

LAND FORM ADJACENT TO THE STREAM (Enter one.)

1. Non-salty basins
2. Salt playa basins
3. Riparian alluvium (perennial flow)
4. Intermittent stream alluvium
5. Foothills (gentle sloping)
6. Low-lying mesas
7. High elevation mesa tops
8. Sedimentary uplands
9. Igneous uplands
10. Steep rocky slopes
11. Cliffs

PHYSICAL SURVEY DATA

Stream Width

Feet today -- The average wetted distance, in feet, from bank-to-bank on day examined. Stream width is estimated at time of spawning for a particular species. Identify.

Turbidity -- Enter, in feet, visibility of pools in appropriate block.

Jackson Turbidity Units (JTUs) -- Enter Jackson Turbidity Units, if known.

Flow - Estimate or determine from formula R = WDCV where:

R = flow in cfs
W = average width of stream, in feet
D = average depth of stream, in feet
C = a constant for bottom
rough - 0.8
smooth - 0.9
V = velocity in feet/second

Gravel, Pool, and Rubble Data -- Identify fish species utilizing survey unit and estimate square yards of good and marginal gravel at spawning time.

Pools -- List area in square yards and range in depths at survey time. If desired, breakdown to 110-yard sections may be undertaken.

Rubble Area -- Enter square yards of rubble, detritus, bedrock or remaining stream habitat.

Gravel (sq. yds.)

Good -- characteristics are:
Diameter of gravel - 1 to 5 inches
Gravel porous - silt and sand minimal

Marginal -- characteristics are:
Mixture of good and unusable gravel (material less than 1" but greater than 5")
Depth of gravel too shallow for effective spawning
Gravel compacted (sand and silt plug intergravel spaces).

Streamside Cover Type -- Check box representing watershed cover type from stream approximately 100 feet back.

FISH, SPECIES, SIZE, AND ABUNDANCE -- For each species, make a rough estimate of numbers and size of fish per typical 100-feet section of stream and enter method of making estimate. It is unnecessary to complete this entry for each 0.25-mile unit examined.

LIMITING FACTORS -- Enter identifying type of barrier, height, if passable or not, and if corrective action is required. Be sure survey extends above impassable barriers and consider all species using stream.

Other -- Describe pollution problems as to source, type, and importance. Identify and describe unscreened diversions, low flow, or flooding problems (include pumping and withdrawals), high temperatures, and any other problems.

ACCESS -- Identify roads, bridges, trails, etc. which will aid future investigation in locating area. Indicate if public or private access is available. It is unnecessary to complete this entry for each 0.25-mile section.

ADDITIONAL COMMENTS -- List comments pertinent to survey which may include more detailed information than space permits under form headings and/or may include:

1. Description of impoundment sites
2. Need for special precautions to protect habitat due to proposed logging, road construction, unstable soils, bank erosion, livestock use, etc.
3. Need for additional studies
4. Sketch of stream

ILLUSTRATION 4

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

LAKE AND RESERVOIR SURVEY REPORT

Date _____
Surveyor _____
District _____
Planning Unit _____

Lake or Reservoir (name)	Location (at or near)	Basin	
County(ies)	Township(s)	Range(s)	Section(s)
State Administration Unit (number)		Code (number)	

PHYSICAL SURVEY DATA

Water (type)	Water (class)	Acre feet of water
Surface (acres)	Shoreline (miles)	Shore development
Elevation (max)	(min)	Water fluctuation (ft)
Width (max)	Depth (max)	Shoal area (less than 20 ft. deep)
Percent NRL	Other .	

Shoreline Composition, visual: Percent Rock _____ Soil _____ Vegetation_____

Shoreline Vegetative Composition, visual: None or sparce cover _____, Grasses/sedges Dominant_____, or Trees Dominant_____ (CHECK ONE)

Habitat Condition: Poor_____ Fair_____ Good_____ Excellent_____.

Habitat Trend: Deteriorating_____ Static_____ Improving_____

Type of Fishery: Cold water_____ Intermediate_____ Warm water_____

TRIBUTARY STREAMS

NAME	LOCATION	FLOW c.f.s	WATER TEMPERATURE

BIOLOGICAL SAMPLING

Emergent aquatic plants (kind)	Abundance
Submerged aquatic plants (kind)	Abundance
Algae [kind(s)]	Abundance

Invertebrates (per 1/3 sq. ft.) number and/or Biomass (use Ekman dredge)

Stonefly	Mayfly	Caddis Fly
Odonata	Diptera	Snails
Clams	Amphipods	Annelids
Other		

Plankton, vertical tow (length) horizontal tow (length)

BOTTOM TYPE (percent)

Bedrock_____ Boulder_____ Gravel_____ Sand_____ Silt_____ Mulch_____ Other_____

Form 6677-2

FISH SPECIES, SIZE, AND ABUNDANCE

Method of collection

SPECIES	NUMBER	LENGTH	WEIGHT	SPECIES	NUMBER	LENGTH	WEIGHT

Species stocked	Size	Frequency

OTHER FACTORS

Accessibility (roads, trails)

Limiting factors

WATER ANALYSIS AND POLLUTION SOURCES

Time	pH	Air Temp. °C	Secchi Disc Reading

Depth	Temp. °C	DO mg/l	Alkalinity Total	Specific Conductivity
Surface				

MANAGEMENT RECOMMENDATIONS AND COMMENTS

INSTRUCTIONS
(Items not listed are self-explanatory)

$$\text{Shore development} = \frac{S}{2\sqrt{\pi A}}$$

S equals the length of the shoreline
A equals the surface area of the lake

APPENDIX 2

Two Catch Depletion Estimator of Seber and LeCren (1967).

The Seber and LeCren two catch depletion estimator is the preferred means for estimating total fish populations by depletion techniques. However, any method that equals or exceeds the precision obtainable by the above method may be substituted (confidence intervals within ± 25% at the 95% level of confidence).

$N = \frac{(C_1)^2}{C_1 - C_2}$ $\quad p = \frac{C_1 - C_2}{C_1}$ $\quad$ N = Population estimate.

p = Estimated proportion. $\quad$ q = 1 - p

C_1 = number of fish taken in first sample (no replacement)

C_2 = number of fish taken in second sample.

s_n^2 (standard error) of $N = \frac{(C_1)^2(C_2)^2(C_1 + C_2)}{(C_1 - C_2)^4}$

s_p^2 of $p = \frac{q(1 + q)}{(N)(p)}$

Seber and LeCren formula applied

$C_1 = 79$

$C_2 = 28$

$N = \frac{C_1^2}{C_1 - C_2}$ $\quad p = \frac{C_1 - C_2}{C_1}$

$N = \frac{79^2}{79 - 28}$ $\quad p = \frac{79 - 28}{79}$

$N = 122$ $\quad p = 0.65$

$$S.E_n = \frac{c_1 \cdot c_2}{(c_1 - c_2)^2}\sqrt{c_1 + c_2}$$

$$= \frac{79 \cdot 28}{(79-28)^2}\sqrt{79+28}$$

$$= 8.8$$

$N \pm 2 S.E.$

$122 \pm 2 \times 8.8$

122 ± 17.6

$q = 1 - p$

$q = 1 - 0.65$

$q = 0.35$

$$S.E._p = \sqrt{\frac{q(1+q)}{1 \cdot p}}$$

$$S.E_p = \sqrt{\frac{0.35(1+0.35)}{122 \cdot 0.65}}$$

$S.E._p = 0.077$

$p \pm 2 S.E. = 0.65 \pm 2 \cdot 0.077$

0.65 ± 0.15

Appendix 2

~~Example 4.5~~ Indices of diversity for nominal scale data. The nesting sites of sparrows.

Category (i)	Observed Frequencies (f_i)		
	Sample 1	Sample 2	Sample 3
Vines	5	1	2
Eaves	5	1	2
Branches	5	1	2
Cavities	5	17	34
$H = \frac{n \log n - \sum f_i \log f_i}{n}$	$[20 \log 20 - (5 \log 5 + 5 \log 5 + 5 \log 5 + 5 \log 5)]/20$ $= [26.0206 - (3.4949 + 3.4949 + 3.4949 + 3.4949)]/20$ $= 12.0410/20 = 0.602$ $H_{max} = \log 4 = 0.602$ $J = \frac{0.602}{0.602} = 1.000$	$[20 \log 20 - (1 \log 1 + 1 \log 1 + 1 \log 1 + 17 \log 17)]/20$ $= [26.0206 - (0 + 0 + 0 + 20.9176)]/20$ $= 5.1030/20 = 0.255$ $H_{max} = \log 4 = 0.602$ $J = \frac{0.255}{0.602} = 0.424$	$[40 \log 40 - (2 \log 2 + 2 \log 2 + 2 \log 2 + 34 \log 34)]/40$ $= [160.0824 - (0.6021 + 0.6021 + 0.6021 + 52.0703)]/40$ $= 10.2058/40 = 0.255$ $H_{max} = \log 4 = 0.602$ $J = \frac{0.255}{0.602} = 0.424$

Continuation of Appendix 2 & 2

diversity. The quantity J has been termed *evenness* (Pielou, 1966) and may also be referred to as *homogeneity* or *relative diversity*.

Example 4.3 demonstrates the calculation of H and J.

4.7 Other Measures of Dispersion

Besides the preceding statistics, we use some other measures, albeit infrequently, to express dispersion. The *semiquartile range* is the distance between the first quartile (25th percentile) and the third quartile (75th percentile). Distances between other quartiles may be used similarly (see Dixon and Massey, 1969, 134–139), for either ratio, interval, or ordinal data.

4.8 The Effect of Coding Data

In Section 3.5 it was shown how coding data may facilitate statistical computations. Such benefits are even more apparent when calculating SS, s^2, and s, because of the labor, and concomitant chances of error, involved in the squaring of unwieldy numbers.

When data are coded by adding or subtracting a constant, all the measures of dispersion except the coefficient of variation are not changed from what they were for the uncoded data, because these measures involve deviations, and deviations are not changed by translation. Sample 1 in Example 4.4 demonstrates these relationships. To arrive at the desired coefficient of variation, simply decode $\bar{X}$ and s before calculating V.

When coding by multiplication or division, however, the measures of dispersion are affected, for the magnitudes of the deviations will be changed. The standard deviation, range, and mean deviation are changed in the same manner as the measures of central tendency (Section 3.5). However, the variance changes as the square of the coding constant, whereas the coefficient of variation is unchanged, as is shown in sample 2 of Example 4.4.

When calculating information-theoretic diversity indices, coding by multiplication or division does not affect the results (see Example 4.3). Coding by addition or subtraction should not be employed.

EXERCISES

4.1 Consider the following data, which are crop yields, in bushels per acre:

24.3, 24.5, 27.2, 29.1, 28.6, 24.1.

(a) Compute the "sum of squares" and the variance of the data by using Equations (4.3) and (4.6), respectively.

(b) Compute the "sum of squares" and the variance of these data by using Equations (4.7) and (4.8), respectively.

Continuation of Appendix 3-3.

Appendix 3-1

4.6 Indices of Diversity

For nominal scale data there is no mean or median to serve as a reference for discussion of dispersion. Instead, we can invoke the concept of *diversity*, the distribution of observations among categories. Consider that sparrows are found to nest in four different types of location (vines, eaves, branches, and cavities). If, out of 20 nests observed, 5 are found at each of the four locations, then we would say that there was great diversity in nesting sites. If, however, 17 nests were found in cavities and only 1 in each of the other three locations, then we would consider the situation to be one of very low nest-site diversity. In other words, observations distributed evenly among categories result in high diversity, whereas a set of observations where the bulk of the data occurs in few of the categories is one exhibiting low diversity.

Of the quantitative descriptions of diversity available, those which are based on *information theory* are quite popular. The underlying considerations of these measures can be explained by considering *uncertainty* to be synonymous with diversity. If 17 out of 20 nest sites are to be found in cavities, then one would be relatively certain of being able to predict the location of a randomly encountered nest site. However, if nests were found to be distributed evenly among the various locations (a situation of high nest-site diversity), then there would be a good deal of uncertainty involved in predicting the location of a nest site selected at random.

The quantitative expression appropriate as a measure of diversity for nominal data is that of Shannon (1948),

$$H = -\sum_{i=1}^{k} p_i \log p_i \tag{4.13}$$

where k is the number of categories and p_i is the proportion of the observations found in category i. Denoting n to be the sample size, and f_i to be the number of observations in category i, then $p_i = f_i/n$. Some mathematical manipulation (see Appendix B) arrives at the equivalent function:

$$H = \frac{n \log n - \sum_{i=1}^{k} f_i \log f_i}{n} \tag{4.14}$$

a formula which is easier to use than (4.13) because it eliminates the necessity of calculating the proportions (p_i) and because of the availability of Table D.5. Any logarithmic base may be used to compute H; bases 10, e, and 2 (in that order of commonness) are the most frequently encountered. Table D.5 utilizes base 10.

However, the magnitude of H is affected not only by the distribution of the data but also by the number of categories, for, theoretically, the maximum possible diversity for a set of data consisting of k categories is

$$H_{max} = \log k. \tag{4.15}$$

Therefore, many users of Shannon's index prefer to calculate

$$J = \frac{H}{H_{max}}, \tag{4.16}$$

thus expressing the observed diversity as a proportion of the maximum possible

Appendix 3-2

A solved example follows:

Given: 3 species

Species 1 = 300 individuals

Species 2 = 200 individuals

Species 3 = 100 individuals

N = 600

$$H' = -\left[\left(\frac{300}{600}\right)\log_2\left(\frac{300}{600}\right) + \left(\frac{200}{600}\right)\log_2\left(\frac{200}{600}\right) + \left(\frac{100}{600}\right)\log_2\left(\frac{100}{600}\right)\right]$$

$$H' = -\left[(.5)\left(\frac{\log_{10} .5}{.301029957}\right) + (.33)\left(\frac{\log_{10} .333}{.301029957}\right) + (.167)\left(\frac{\log_{10} .167}{.301029957}\right)\right]$$

$$H' = -\left[(.5)\left(\frac{-.301029996}{.301029957}\right) + (.333)\left(\frac{-.477553377}{.301029957}\right) + (.167)\left(\frac{\quad}{\quad}\right)\right]$$

$$H' = -\left[(.5)(-1.000000) + (.333)(-1.586901) + (.167)(-2.582080)\right]$$

APPENDIX 4

The Shannon-Wiener Diversity Index (sometimes shown as Shannon-Weaver) is one of the most widely used indices and is based on information theory. Generally, it is expressed in logarithms to the base 2, but may also be expressed in natural (e), or common logs (base 10). Because it is based on uncertainty of encounter, rather than on certainty of encounter, it is best considered a lack of diversity index. As the index number increases, so too does the uncertainty of encountering the same species twice within the population being investigated. Differences in both species richness and species evenness will affect the index number. Past workers have used the index for monitoring organic pollution, toxic substances and continued static stress in ecosystems. 5/

$N^1 = \sum_{1-\Lambda} \left(\frac{N_1}{N}\right) \text{Log}_2 \left(\frac{N_1}{N}\right)$, where N^1 = Shannon-Wiener Index, N_1 = number of individuals in the ith species, and N = total number of all individuals in all species. Log_{10} or Log_e can be used to derive Log_2 values. The appropriate log value is determined for the $\frac{N_1}{N}$, and if Log_{1C} is used the value is divided by 0.3010299957, if Log is used the value is divided by 0.6931471806 (values can be rounded to 5 places if desired). Answers are then in Log_2 form. Solving of the rest of the equation is as shown.

APPENDIX 4

The Shannon-Wiener Diversity Index (sometimes shown as Shannon-Weaver) is one of the most widely used indices and is based on information theory. Generally, it is expressed in logarithms to the base 2, but may also be expressed in natural (e), or common logs (base 10). Because it is based on uncertainty of encounter, rather than on certainty of encounter, it is best considered a lack of diversity index. As the index number increases, so too does the uncertainty of encountering the same species twice within the population being investigated. Differences in both species richness and species evenness will affect the index number. Past workers have used the index for monitoring organic pollution, toxic substances and continued static stress in ecosystems. 5/

$$N^1 = \sum_{i=1} \left(\frac{N_1}{N}\right) \log_2 \left(\frac{N_1}{N}\right)$$, where N^1 = Shannon-Wiener Index,

N_1 = number of individuals in the ith species, and N = total number of all individuals in all species. Log_{10} or Log_e can be used to derive Log_2 values. The appropriate log value is determined for the $\frac{N_i}{N}$, and if Log_{10} is used the value is divided by 0.3010299957, if log is used the value is divided by 0.6931471806 (values can be rounded to 5 places if desired). Answers are then in $\log_2$ form. Solving of the rest of the equation is as shown.